

Paper

Curved-Pentagonal Planar Monopole Antenna for UHF Television Broadcast Receiving Antenna

Rudy Yuwono, Endah Budi Purnomowati, and Mohamad Yasir Amri

Department of Electrical Engineering, Faculty of Engineering, University of Brawijaya East Java, Indonesia

Abstract—A planar monopole antenna is an aerial, which the radiating element is perpendicular to the ground plane. It has five equal curvy sides and works at Ultra High Frequency (UHF) band of terrestrial broadcast 478–806 MHz. The curvy sides are made of five equal trimmed ellipses and separated 72° each ellipse to another, form pentagonal shape. Optimizations are obviously necessary to gain the antenna performance at the desired frequency range. The dimensions to optimize this antenna performance are the length of the sides, the offset of curvature, the antenna height from the ground plane, and the ground plane size. Optimization process is done by simulating the proposed antenna with calculated designs using Computer Simulation Technology (CST) Studio Suite 2015 software. The optimized antenna design then fabricated with a $75\ \Omega$ coaxial line fed, measured, and results: Voltage Standing Wave Ratio (VSWR) range of 1.05–1.28, antenna gain at 600 MHz is 15.33 dBi, elliptical polarized, and omnidirectional. With these features, this antenna should satisfy the requirements of UHF television broadcasting.

Keywords—planar monopole antenna, television broadcasting, UHF band.

1. Introduction

A planar monopole antenna is a kind of aerial, which has planar element instead of wire. The planar element is located at the distance h above the ground plane [1]. This replacement with various shapes of planar element, increases the surface areas of the monopole and has direct impact on bandwidth [2]. Planar monopole antenna has wide range of frequency and yields various applications.

Terrestrial broadcast TV antenna operates in UHF at 478–806 MHz band. Today there are many Yagi-Uda and wire antennas used in such applications.

Planar monopole antennas have several common shapes such as circular, elliptical, square, rectangular, hexagonal, pentagonal, and provide wide impedance bandwidth. The circular monopole [1], [3] and the elliptical monopole [4] were reported maximum bandwidth [3], [5]. Hammound in [5] analyzed that square monopole provides smaller bandwidth but the radiation pattern suffers less degradation within the impedance bandwidth.

Since planar monopole antenna has a wide range of frequency and easy to manufacture by using aluminum as construction the material, it is realizable to build one as

terrestrial television broadcast receiving antenna with better shape and design (Fig. 1).

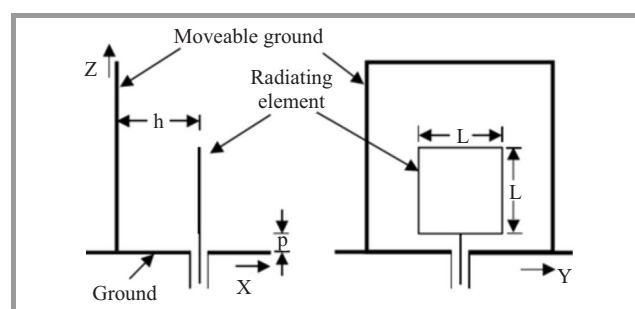


Fig. 1. Parts of planar monopole antenna [1].

Some of the planar monopole features are:

- planar monopole antennas provide wide impedance bandwidth,
- they have multiband operations capability and have omnidirectional radiation pattern [6], [7],
- theirs electrical heights are less than $\lambda/4$ [7]–[10].

2. Antenna Design

The main idea of this antenna type is based on additional curvy edges added to a pentagonal shape. The dimensions of the shapes are adjusted to gain the performance [11], [12]. As mentioned before, the shape of rectangular in planar monopole provides less degradation radiation pattern, while the elliptical shape provides the

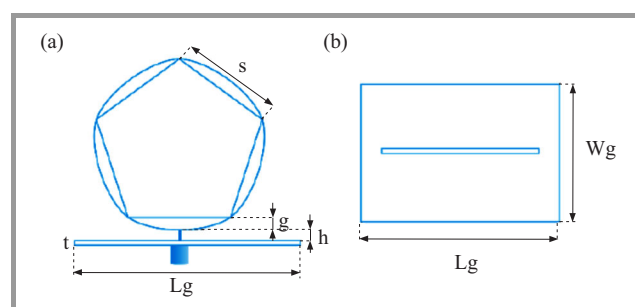


Fig. 2. Antenna design: (a) front view, (b) top view antenna design. (See color pictures online at www.nit.eu/publications/journal-jtit)

maximum bandwidth [13], [14]. Figure 2 shows the basic antenna geometry.

To maintain a standard shape of curvy sides, an ellipse is used as the component of the curvature. The offset is set by configure the ratio of ellipse (Fig. 3).

The side of pentagon is set by trim the ellipse in a distance of y from its center with equation below where s is the length of pentagon's sides, a is the major radius and b is the minor radius of ellipse, where $a = \frac{\lambda}{n-1}$, b is adjusted by the ratio to maintain the desired offset and n is the number of harmonic of lower operating channel frequency, i.e. 478 MHz.

$$y = \frac{b}{2} \cdot \sqrt{1 - \left(\frac{s/2}{a/2}\right)^2} \quad (1)$$

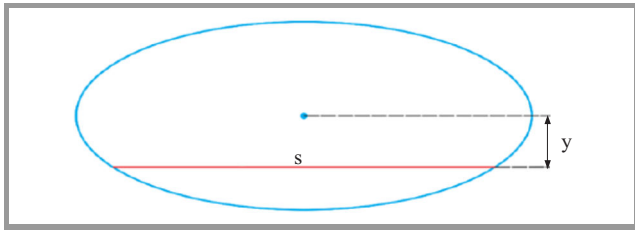


Fig. 3. Trimming position to get the curve and pentagon's side s .

Trimmed ellipse would be duplicated into five shapes and arranged at the distance 72° after each shapes as shown in Fig. 4.

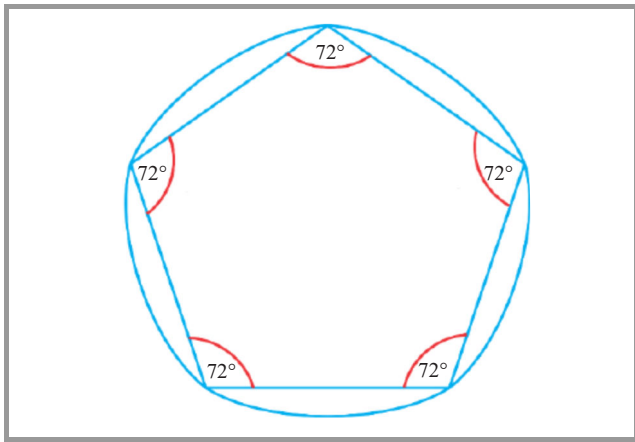


Fig. 4. Trimming position to get the curve and pentagon's side s .

Table 1

Comparison of different variable weight codes properties

Parameter	Description	Value [mm]
t	Base aluminum thickness	2
h	Radiating element distance from ground plane	10
g	Curve offset	0
Lg	Ground plane length	700
Wg	Ground plane width	700
s	Pentagonal side length	628

Initial antenna dimensions' before optimization are listed in Table 1 and are base to approximations for the first s , infinite for ground plane, and for h . After the initial dimensions are defined, then simulation is proceed with CST software.

3. Simulation and Measurement

The simulation process helps to define the best dimensions that yields the best performance antenna by the result of optimizations based on parameters, i.e. VSWR based bandwidth, radiation pattern, polarization, and gain.

Figure 5, shows the VSWR with the variation of s based on Table 1. One can see that $\lambda/5$ antenna is the best in 387 MHz bandwidth.

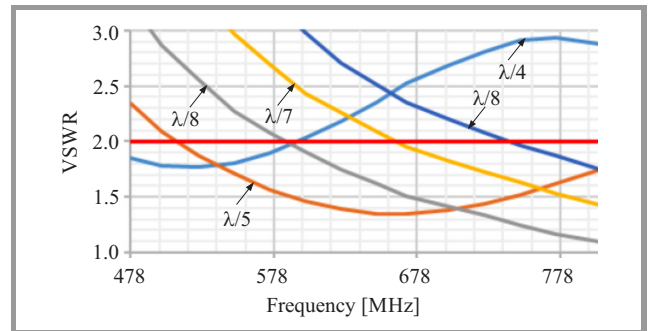


Fig. 5. VSWR vs. frequency on s dimension optimization.

Offset for the curvature from the pentagon's side to the edge of curvature optimizations result can be represent by the Fig. 6. The best performance has antenna with 15 mm offset.

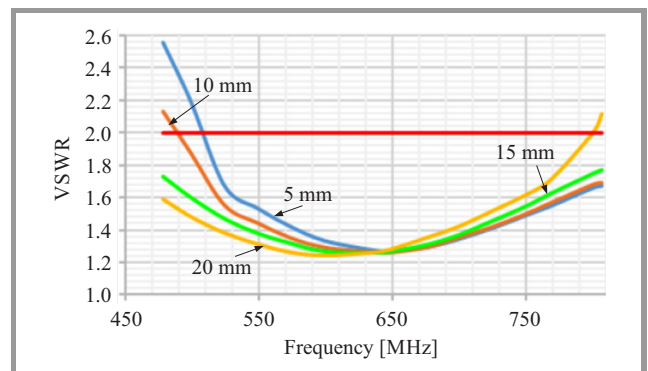


Fig. 6. VSWR vs. frequency on g dimension optimization.

The distance of the radiating element with ground plane does have influence to the performance. The performance slightly increasing when it reached 7 mm on antenna $h = 0.7$ (Fig. 7). The best performance is achieved by antenna $h = 0.8$ which has the lowest VSWR.

To maintain the best performance, the size of ground plane is optimized by adjusting the Lg and Wg (Fig. 2b). The change of ground plane does not influence VSWR perfor-

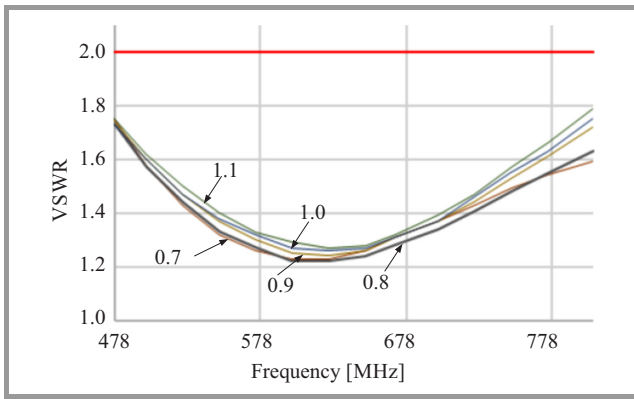


Fig. 7. VSWR vs. frequency on h dimension optimization.

mance a lot, yet influence the gain of the antenna. The optimized values are $W_g = 8$ cm and $L_g = 26$ cm, which resulted bandwidth of 328 MHz and gain at its middle frequency of 3.45 dBi.

The optimized for best performance dimensions are listed in Table 2.

Table 2
Optimized antenna parameters

Parameter	Description	Value [mm]
t	Base aluminum thickness	2
h	Radiating element distance from ground plane	8
g	Curve offset	15
L_g	Ground plane length	80
W_g	Ground plane width	260
s	Pentagonal side length	125.6

3.1. Measurement Results

The designed antenna was then fabricated and measured in antenna laboratory. The observed parameters were VSWR, radiation pattern, gain, and polarization.

Figure 8 shows the VSWR performance of the antenna. It can work in the entire band and the best performance is 1.02 at the 700 and 750 MHz.

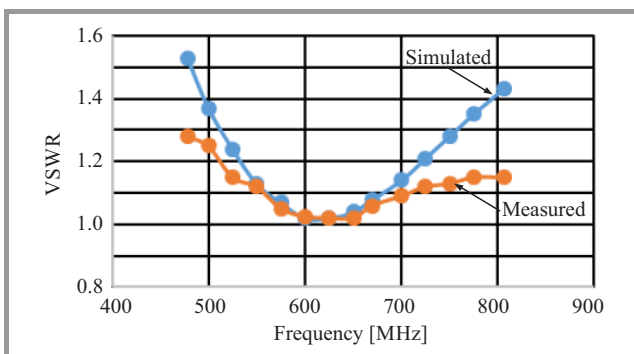


Fig. 8. VSWR within frequency band.

Polar diagram in Fig. 9 shows that the radiation pattern of this antenna is omnidirectional with stronger area at both front and back side.

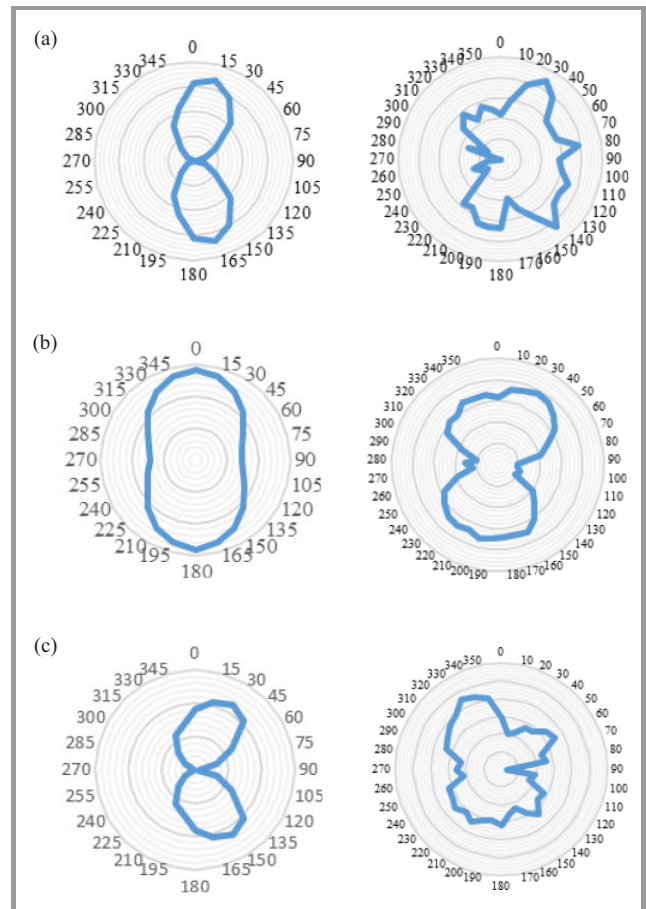


Fig. 9. Simulated (left) and measured (right) result of radiation pattern: (a) sweep φ at $\theta = 90^\circ$, (b) sweep θ at $\varphi = 0^\circ$, (c) sweep θ at $\varphi = 90^\circ$.

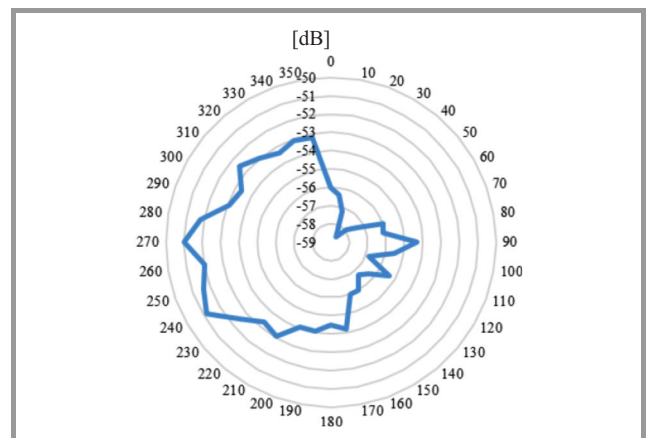


Fig. 10. Polar diagram of the receive level sweep φ at $\theta = 0^\circ$.

The polar diagram of the receive level of the antenna sweep φ at $\theta = 0^\circ$ shown in Fig. 10 that the polarization of the antenna is ellipse. Because it receives the signal poorly on $3-82^\circ$ and receives better at $81-360^\circ$.

Gain measurement (Fig. 11) shows that the antenna has gain average of 3.90 dBi and tend to increase along the higher frequencies.

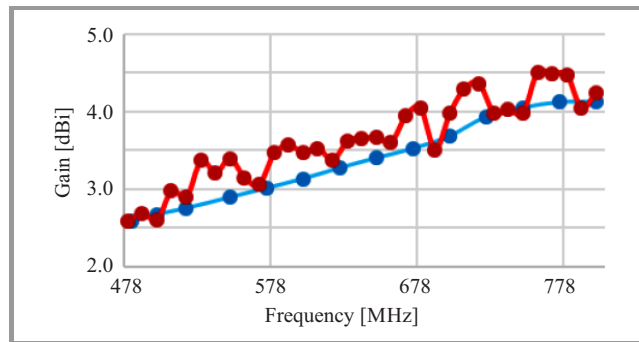


Fig. 11. Gain vs. frequency.

The change of antenna components size influence the performance:

- Wider curve offset g yields wider VSWR bandwidth with optimum at 15 mm.
- Shorter distance yields better VSWR bandwidth with optimum at 8 mm.
- Tighter length of sides s yields wider bandwidth and shifting to the higher frequency with optimum at 125.6 mm.
- Tighter ground plane L_g yields higher gain with optimum at 80 mm.
- Narrow ground plane W_g yields higher (optimum at 260 mm).

4. Conclusion

The proposed antenna has omnidirectional radiation pattern with almost equally stronger area at front and back, elliptical polarized, VSWR bandwidth of 3:1 worked at 300–900 MHz with average gain of 3.90 dBi. The antenna can be operated as TV broadcast receiver at UHF band (478–806 MHz).

Acknowledgement

This research is supported by Ministry of Research and Technology and Higher Education, the Republic of Indonesia for supporting this research under BOPTN 2015 and BOPTN 2016 batch research scheme.

References

- [1] E. Lee, P. S. Hall, and P. Gardner, "Compact wideband planar monopole antenna", *Electron. Lett.*, vol. 35, pp. 2157–2159, 1999.
- [2] R. Singh and G. Kumar, "Broadband Planar Monopole Antennas", M.Tech. credit seminar report, Electronic systems group, EE Dept., IIT Bombay, Nov. 2003.

- [3] Y. Rudy, A. Baskoro, and A. D. Erfan, "Design of circular patch microstrip antenna for 2.4 GHz RFID applications", in *Future Information Communication Technology and Applications*, H.-K. Jung, J. T. Kim, T. Sahama, C.-H. Yang, Eds. *LNEE*, vol. 235, pp. 21–28. Springer, 2013.
- [4] S. Honda, M. Ito, H. Seki, and Y. Jingo, "A disc monopole antenna with 1:8 Impedance bandwidth and omnidirectional radiation pattern", in *Proc. of ISAP'92*, Sapporo, Japan, 1992, pp. 1145–1148.
- [5] M. Hammoud, P. Poey, and F. Colombel, "Matching the input impedance of a broadband disc monopole", *Electron. Lett.*, vol. 29, pp. 406–407, 1993.
- [6] S. Y. Lin, "Multi-band Planar Monopole Antenna for Handset", IEEE, 0-7803-7846-6/03, 2003.
- [7] R. Yuwono, R. Syakura, and D. F. Kurniawan, "Design of the Circularly Polarized Microstrip Antenna as RFID Tag for 2.4 GHz of Frequency", *J. Comput. & Theoret. Nanosci.*, vol. 21, no. 1, 2015 (doi: 10.1166/asl.2015.5753).
- [8] J. Y. Jan and L. C. Tseng, "Planar Monopole Antennas for 2.45/5.2 GHz Dual-Band Application", IEEE, 0-7803-7846-6/03, 2003.
- [9] C. A. Balanis, *Antenna Theory*, 2nd ed. New York: Wiley, 1997.
- [10] R. Yuwono and R. Syakura, "2.4 GHz circularly polarized microstrip antenna for RFID application", in *Advanced Computer and Communication Engineering Technology*, H. A. Sulaiman et al., Eds. *LNEE*, vol. 315, pp. 37–42. Springer, 2015 (doi: 10.1007/978-3-319-07674-4_4).
- [11] A. Ruengwaree, R. Yuwono, and G. Kompa, "A noble rugby-ball antenna for pulse radiation", in *Proc. Eur. Conf. Wirel. Technol.*, Paris, France, 2005, pp. 455–458 (doi: 10.1109/ECWT.2005.1617755).
- [12] K. L. Wong, C. H. Wu, and S. W. Su, "Ultra wide-band square planar metal-plate monopole antenna with trident-shape feeding strip", *IEEE Trans. Antenna & Propag.*, vol. 53, no. 4, pp. 1262–1269, 2005.
- [13] R. Yuwono, I. Mujahidin, and A. Mustofa, "Rectifier using UFO microstrip antenna as electromagnetic energy harvester", *Adv. Sci. Lett.*, vol. 21, no. 11, pp. 3439–3443, 2015 (doi: 10.1166/asl.2015.6574).
- [14] R. Yuwono and R. Syakura, "Star-L-shaped circularly polarized ultra-wideband microstrip antenna for wireless applications", *Appl. Mech. & Materials*, vol. 548–549, pp. 776–779, 2014 (doi: 10.4028/www.scientific.net/AMM.548-549.776).



Rudy Yuwono received his B.Sc. from University of Brawijaya, Malang, Indonesia, in 1997 and M.Sc. from University of Kassel, Germany, in 2005. Currently, he is working at Electrical Engineering, University of Brawijaya Malang as Lecturer and Researcher. His research interest are antenna and propagation, microwave and

wireless communication.

E-mail: rudy_yuwono@ub.ac.id

Faculty of Engineering

Department of Electrical Engineering

Brawijaya University

MT. Haryono st 167 Malang

East Java, Indonesia



Endah Budi Purnomowati received B.Sc. from ITS, Surabaya Indonesia in 1982 and 1996, respectively. She is with at Electrical Engineering, University of Brawijaya Malang. Her areas of interest is mobile communication. She is a researcher at Telecommunication Laboratory, Electrical Engineering, University of Brawi-

jaya Malang.

E-mail: endah_budi@ub.ac.id

Faculty of Engineering

Department of Electrical Engineering

Brawijaya University

MT. Haryono st 167 Malang

East Java, Indonesia



Mohamad Yasir Amri received his B.Sc. in Electrical Engineering from Brawijaya University, Indonesia, in 2016. From 2012 to 2014 he has been working as a laboratory assistant of Transmission and Microwave Laboratory Brawijaya University. His research and development interests are mostly about antenna design, included

analysis, simulation, measurement, and optimizations of antenna design.

E-mail: amrimyw@gmail.com

Faculty of Engineering

Department of Electrical Engineering

Brawijaya University

MT. Haryono st 167 Malang

East Java, Indonesia